VOLUME XXX NUMBER 1 WHOLE NUMBER 250

THE JOURNAL

OF

THE ROYAL ASTRONOMICAL SOCIETY OF CANADA

DEVOTED TO THE ADVANCEMENT OF ASTRONOMY AND ALLIED SCIENCES

EDITOR
C. A. CHANT
David Dunlap Observatory
Richmond Hill P.O., Ont.

ASSOCIATE EDITORS
R. MELDRUM STEWART
Director of the Dominion Observatory
Ottawa

W. E. HARPER
Acting Director of the Dominion Astrophysical Observatory,
Victoria, B.C.

J. PATTERSON
Director of the Meteorological Service of Canada, Toronto

PUBLISHED MONTHLY
(Ten numbers per year)

January, 1936

PRINTED FOR THE SOCIETY
TORONTO: 198 COLLEGE ST.

THE JOURNAL
OF
THE ROYAL ASTRONOMICAL SOCIETY OF CANADA

VOL. XXX, No. 1 JANUARY, 1936 WHOLE No. 250

Articles PAGE

The Application of the Spectroscope to Astronomy. (With plates I—IV) ..... *R. K. Young* 1

The Total Eclipse of June 19, 1936 14

Radio Talks over CFCT, Victoria, B.C.
No. 77, Mining for Meteorites; No. 78, Surface Temperatures of the Planets ..... *W. E. Harper* 15

Review of Publications

Die Beobachtung veränderlicher Sterne, by R. Müller (*F.S.H.*); *Amateur Telescope Making*, ed. Ingalls (*C.A.C.*); *Worlds Without End*, by H. S. Jones (*C.A.C.*) 22

Meteor News

Photographic Observations of the Leonids, 1935 (with plate V); Visual Observations of the Leonids, 1935; The Relative Numbers of Leonids during Recent Years ..... *P.M.M.* 25

Notes and Queries

New Velocities of Extra-galactic Nebulae ..... *C.I.C.* 31

Upon request, made previous to publication of article, contributors will be supplied free either with fifty copies of the issue containing the article, or with the sheets containing the article attached to a printed cover. If separate reprints are desired the cost will be as follows:

	4 pp.	8 pp.	12 pp.	16 pp.	20 pp.	24 pp.
50 copies	$3 50	$5 50	$ 9 50	$10 00	$13 00	$16 00
100 copies	4 00	7 00	10 00	11 00	14 00	18 00
200 copies	4 50	8 00	11 00	12 00	15 50	20 00

Covers, extra, 50 copies, $1.50; 100 copies, $2.00; 200 copies, $2.50.

Business correspondence, remittances, etc., should be addressed to J. H. Horning, Treasurer of the Society, 198 College Street, Toronto.

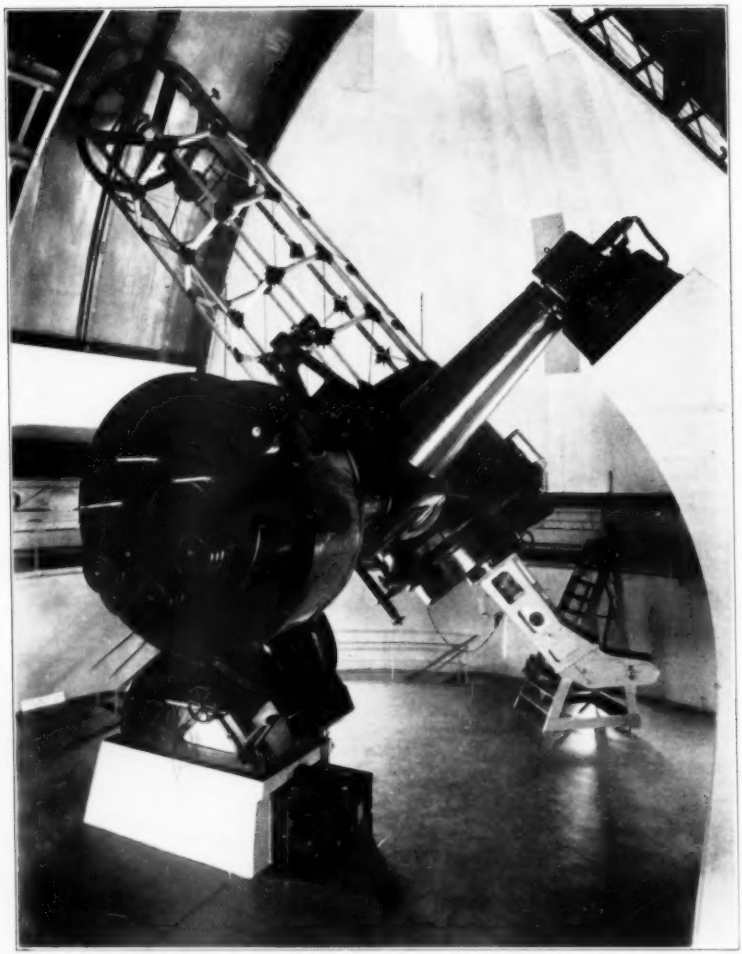
Communications regarding Library matters should be addressed to the Librarian.

$2.00 per annum. Single numbers, 25 cents.

Subscription to the JOURNAL is included in membership fee.

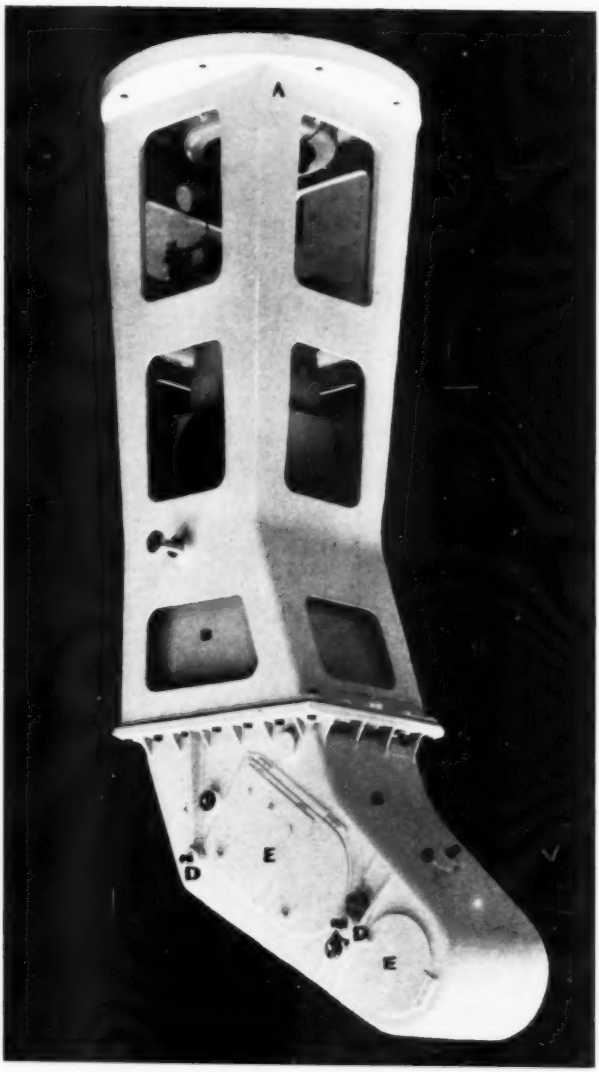
Amateur Telescope Makers may obtain crown glass discs, achromatic objectives, diagonals and eyepieces, abrasives, pitch, rouge, chemicals, brass bar and tubing, in good quality at reasonable prices, from Anglo-Canadian Importing Co., 510 Westminster Trust Bldg., New Westminster, B.C.

PLATE I.



THE 74-INCH TELESCOPE WITH SPECTROGRAPH ATTACHED.

PLATE II.



NEARER VIEW OF THE SPECTROGRAPH.

A, attaching frame; B.B, heating case attached rigidly to frame; C.D.D, bolts supporting the inside box; E.E, doors giving access to spectrograph.

VIEW OF THE SPECTROGRAPH WITH DOORS OPEN.

C.C., the supporting toggle bolts in the meridian plane; T.T, similar supports in a perpendicular plane, the same as D.D. in Plate II; F, covers plate of receptacle for plate holder, 25-inch camera. The plate holder is seen in position for the 12½-inch camera.

PLATE IV.

SPECTRUM OF α TAURI WITH IRON ARC COMPARISON.
The displacement corresponds to a velocity of 34.4 km. recession.

THE JOURNAL
OF
THE ROYAL ASTRONOMICAL SOCIETY
OF CANADA

Vol. XXX, No. 1 JANUARY, 1936 Whole No. 250

THE APPLICATION OF THE SPECTROSCOPE TO ASTRONOMY*

By R. K. YOUNG

(With plates I-IV)

THE spectrum of a star contains five distinct features which can be investigated:

(1) The intensity of the continuous background as a function of the wave-length.
(2) The identification of the absorption lines with those originating in terrestrial sources.
(3) The measurement of the intensity of the absorption lines.
(4) The determination of the contours of the absorption lines, that is, the intensity of the absorption in any line as a function of the position in the line.
(5) The position of the lines.

This lecture will treat of the manner in which the position of the lines is used in astronomy. In a subsequent lecture Dr. Hogg will speak of investigations which are based on the other four observable quantities.

The positions which the lines in the spectrum occupy depend on the wave-length of light to which they owe their origin, but this is subject to small variations depending on the speed with which the observer is approaching or receding from the source of light. If the motion is one of approach, the lines will be shifted toward the violet; and if the motion is one of recession, the lines will be shifted toward the red. If there is no relative approach or recession of the

*An illustrated lecture at the University of Toronto, December 13, 1935.

observer and source, the line will be in its normal position or have its normal wave-length, which wave-length is determined by observing laboratory sources. By measuring the magnitude of the shift in the spectrum the relative velocity of the observer and source can be determined, for the shift is proportional to this velocity according to the equation

$$\frac{\Delta\lambda}{\lambda} = \frac{v}{c}$$

where λ is the normal wave-length of the line and $\Delta\lambda$ is the measured shift, both being measured in the same units. The customary unit is the Angstrom which is 10^{-10} metre; v is the relative rate of approch of the observer and the source, usually measured in kilometres per second, and c the velocity of light also in kilometres per second. Thus if we are measuring the position of the hydrogen line Hγ whose wave-length is 4340 Angstroms and the measured shift is 0.29 Angstrom then the relative velocity is given by

$$v = \frac{299{,}860 \times 0.29}{4340} = +20 \text{ km. per sec.}$$

The source and the observer are separating with a velocity of 20 kilometres per second. We usually speak of this velocity as the *radial* velocity because it is along the radius vector joining the observer and the source. The spectroscope gives no indication of velocity at right angles to the radius vector. This latter component of velocity must be determined by some other means.

The spectrograph which is attached to the 74-inch telescope of the David Dunlap Observatory has been designed especially to determine the positions of the absorption lines in stellar spectra and thus to determine the radial velocity of the stars. In the design of a spectrograph for this purpose two major difficulties are encountered. Firstly, the light of the stars is very feeble; and secondly, the measured shifts are small and hence the instrument must be built rigidly and many sources of error guarded against in order to minimize observational errors.

A star of zero magnitude (and there is one star only in the sky brighter than this) is equivalent in brightness to a candle at a distance of 0.4 mile. A star of the fifth magnitude, which is about

the limit of naked-eye observation on an ordinary night, is equivalent to a candle at the distance of 4 miles. At present we are observing stars around the 7th magnitude. These stars give about the same amount of light as a candle at a distance of 10 miles. We hope to observe stars down to the 10th magnitude; a star of that magnitude gives about the same amount of light as a candle does at a distance of 40 miles.

The exceedingly minute available intensities of light require a spectrograph with small dispersion and this accentuates the second difficulty of building the instrument so that the measured displacements will give reliable velocities. In the one-prism spectrograph which we are using a velocity of one kilometre per second in the source of light produces a displacement of Hγ of 1/2280 mm. When one bears in mind that the exposures may extend to two hours or more and that during this time the position of the spectrograph is constantly changing, one can appreciate how rigidly it must be built in order that fictitious displacements may not mask the small shifts caused by the stellar velocities.

Plate I shows the instrument attached to the telescope and a nearer view is shown in Plate II. A heavy silicon-aluminum casting *A* attaches the spectrograph to the telescope by eight bolts, the holes for which may be seen. The spectrograph proper is a heavily ribbed silicon-aluminum box supported within an outer felt-lined heating case marked *B*, *B* on the plate. The heating case is strong and rigid and is attached as an integral part of casting *A*. Part of the spectrograph box may be seen through the open doors of the heating case illustrated in Plate III. This plate also shows the manner in which the spectrograph box is supported by the heating case. In the meridian plane it rests on two toggle bolts *C*, *C*, and its position at right angles to this plane is controlled by four toggle bolts, two of which on the one side are shown at *T*,*T*. These two are opposed to a corresponding pair on the other side of the case. The upper end of the box is supported by the heating case on a universal bearing and is free to move in any direction. Thus the spectrograph box is cradled in the attaching frame in such a way that no strains in the latter can be transmitted to the box.

The optical parts of the spectrograph consist of (*a*) a collimating

lens which is a cemented doublet of 2¾ inches clear aperture and 49½ inches focal length, (*b*) a glass prism made from Parsons' glass DF3, and (*c*) two camera lenses of the cemented triplet type with clear apertures of 3 inches, which may be used alternatively to give cameras of 25 or 12½ inches focal lengths. The change from the shorter to the longer camera is effected by changing the lens and altering the position of the plate-holder. The plate-holder is shown in Plate III in position for the 12½-inch camera. It con-

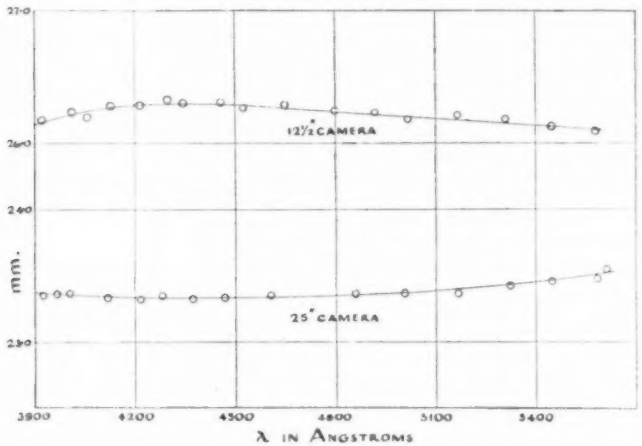


FIG. 1.—Focal curves of 12½- and 25-inch cameras. Ordinates are camera settings magnified 20 times.

sists of a short cylinder running transversely through the spectrograph box and held in position by four knurled screws. It can be removed very quickly and slid into the receptacle covered by the plate *F* when the 25-inch lens is in place.

The focal curves of the two lenses are shown in figure 1. The 25-inch lens gives a field slightly convex to the lens while the field of the 12½-inch lens is slightly concave. From λ3900 to λ5600 both give a flat focus to within 0.1 mm. In the particular test from which these curves were drawn, the tilt was adjusted to give

the best focus from λ3900 to λ5000, which is the region of the spectrum to which the ordinary dry plate is sensitive.

Spectra of 7th magnitude stars may be obtained with the 25-inch camera, using a slit width 0.05 mm., under average conditions of seeing and state of the silver coat on the main mirror of the telescope in about 70 minutes. With good seeing and a first class silvered surface the exposure would be less than half this.

Both lenses give excellent definition. The general appearance of the spectra and the definition may be judged from Plate IV which shows a portion of the spectrum of α Tauri. The resolving power of the prism at Hγ is about 39,000 and the purity with ordinary plates and normal slit width about 10,000. This particular star has numerous well-defined lines in its spectrum and is consequently adapted for accurate velocity measures. The measured displacement corresponds to a velocity of recession of 54.5 km. with a probable error of 0.4 km. per sec. A single velocity determination will ordinarily have a much larger probable error than this, and for stars with very few or poorly defined lines it may reach 10 km. per sec. or more.

We shall assume now that we can obtain the velocity with which the stars are moving and shall consider what information about the stars and the universe as a whole can be, or has been, obtained from such data.

Stars with Variable Velocity

Radial velocities have been determined for about 5000 stars. These are the bright stars mostly. Much work remains to be done on the fainter stars. Velocities from 10 to 40 kilometres per second are very common while larger velocities are more rare. Occasionally stars are found with velocities greater than 100 or even as high as 200 kilometres. One of the remarkable discoveries in connection with the observations for velocity was that many stars show a variable velocity. The lines in the spectrum shift backward and forward, indicating that the star is sometimes approaching and sometimes receding from the observer. Starting with a certain velocity of approach on a given date it will be observed after a time to be approaching more rapidly. In the course of a few days, the

velocity of approach will reach a maximum and then diminish, so that in the course of several days it will be at rest. The change in velocity is perfectly continuous and the star begins to recede until a maximum velocity of recession is reached, and after a few days more the star will be found to be approaching the observer at its original rate. The whole phenomenon is periodic and perfectly regular for any star. Different stars may show periods ranging from a few hours to several months or years. Almost always the different phenomena can be completely explained by supposing that the star is double and that the bright star is revolving round an unseen companion, too close to be seen as a visual double even in the most powerful telescopes. In quite a large fraction of the stars showing variable velocity both spectra can be seen. The absorption lines are double and oscillate backward and forward, shifting in opposite directions. In this case both stars are bright. From a study of the velocities during the duration of the period of variation the details of the orbit may be determined. These include the velocity of the system, the shape of the orbital ellipse and the orientation of the major axis. The projected length of the axis of the ellipse on a plane perpendicular to the line of sight may also be obtained and in addition the so-called mass function

$$\frac{m_2^3 \sin^3 i}{(m_1+m_2)^2}$$

in which m_1 and m_2 are the masses of the two bodies in terms of the sun's mass and i is the inclination of the orbit. In the case of a double-line spectrum the ratio of the masses can be found also.

The number of spectroscopic binaries now known exceeds 1300 and orbits have been determined for about 300. Over 50 per cent. have periods less than 10 days and 75 per cent. less than 100 days. These figures probably have no relation to the actual frequency distribution of periods among the binary stars, because the binaries with short periods are easy to discover and the orbit is quickly determined. There is need of more observations and the determination of orbits among the stars showing longer periods. There are however significant relations between the length of the period, the type of the star and the shape of the orbit. The early spectral types have uniformly short periods, the stars in the system are not

far apart and they revolve in circular orbits. As the type changes to the later divisions the stars are farther apart, the periods are longer and the orbits more eccentric. For the very long periods the spectroscopic binaries merge with the visual double stars and there seems to be no sharp line of demarcation between them. A mathematical treatment of the probable history of a rotating gaseous star shows that it can become unstable and divide into two. At first the stars revolve almost in contact, but tidal action pushes them apart and increases the period. There is a very satisfactory agreement between theory and observation, that is to say, the observations are very satisfactory and theory can be made to agree.

The orbital elements also tell us something of the masses of the stars, and this is important because there are very few ways in astronomy of arriving at the masses of the stars. For those stars which show double lines the quantities $m_1 \sin^3 i$ and $m_2 \sin^3 i$ can be found. We do not know the value of i but for a large number of binaries we may assume an average value for it. The great majority of stars have masses comparable to that of our own sun. The mass of an average star may lie between 1½ to 2 times that of the sun, while stars with 10 times the sun's mass are rare. Uniformity in regard to mass may be said to be one of the outstanding features of the stars.

The Velocity of the Sun

The rate at which a star is moving toward or away from us is determined, in the first instance, relative to the earth. It is well known that the earth revolves about the sun and consequently must be carried toward or away from the star by amounts which depend on the time of the year. To calculate and allow for this varying motion of the earth is a simple geometrical problem, so that the velocities of the stars when published are freed from this correction. When the velocity of a star is quoted as +20 km. per sec. we mean that the star is receding from the sun at this rate. The recession may be due to the star's motion or it may be due to the sun. However an inspection of the velocities of several stars shows at once that all the stars must be moving and we infer that our own sun is not at rest either. The sun is moving under the resultant attraction of all the universe of stars around us.

Observations of radial velocity supply the best method of determining the direction and magnitude of this solar motion. There are no fixed axes of reference and the velocity of the sun so determined is relative to the centre of the stars used. We speak of the direction of the sun's motion as the solar *apex* and the opposite direction as the *antapex*. Relatively to the naked-eye stars the sun is approaching that part of the sky near the bright star Vega with a velocity of about 20 km. per sec. Whether this is the sun's velocity in space depends on the motion of the naked-eye stars as a whole.

The Mean Distance of the Stars

When the velocity of the sun and the direction of its motion relative to any group of stars have been obtained, a simple formula will tell what part of the observed velocity of a star is caused by the sun and what by the star. It is thus possible to free the observed stellar velocities from the solar motion. The radial velocity of a star corrected for the solar motion is called its *peculiar* motion. Peculiar motions are the motions of the stars relative to the whole group of stars which has been used in determining the solar motion.

If we take the mean of the peculiar velocities of any group of stars in a fairly limited region of the sky we should, on the hypothesis of random motion, obtain an algebraic average zero. The arithmetic average, that is the mean taken without regard to sign, would be the average speed in the line of sight of the group. The line of sight is a particular direction, and we are fairly well justified in assuming that the average velocity of the group of stars is the same in any other particular direction. The velocities which the stars of the group possess in a plane perpendicular to the line of sight causes a displacement of the stars on the celestial sphere, measured in arc, known as their *proper motion*. The whole proper motion is due not only to their own velocity but a part is also due to the solar motion. There is a component of the proper motion which lies in a plane perpendicular to the plane containing the star, the sun and the apex which arises from the star's motion alone. This is called τ component. It will be observed that the τ component of proper motion is the visible effect on the stars arising from a

velocity in a particular direction and which we can equate to the mean radial velocity. This assumption leads to a simple formula for the mean parallax of the group of stars,

$$\pi = 4.74 \frac{\tau}{V}.$$

Stated in words, this formula reads:

The mean parallax of a group of stars is equal to 4.74 times the mean τ component of proper motion divided by the mean peculiar velocity of the same stars.

The formula does not apply to an individual star but to a group only. There is no disadvantage particularly in obtaining this mean rather than the individual parallaxes, because if we were in possession of the actual parallaxes of all the stars, the first thing we should do would be to group them together in various ways and consider how their mean parallaxes compared.

We could for instance group the stars according to their apparent magnitudes and determine the mean parallax of stars of the various apparent brightnesses. The results due to Seares are shown below:

Magnitude	Mean Parallax	Magnitude	Mean Parallax
	"		"
1	0.083	7	0.0082
2	0.056	8	0.0056
3	0.038	9	0.0039
4	0.026	10	0.0027
5	0.018	11	0.0018
6	0.012	12	0.0009

In converting these mean parallaxes into mean distances on the basis that a star with a parallax of one second of arc is 3.26 light years away, the mean distance so obtained is the harmonic mean.

Or we could again group the stars according to spectral type. This has been done by Campbell who finds for the naked-eye stars the following values:

Type	Mean Parallax	Type	Mean Parallax
	"		"
B	0.0066	G	0.0086
A	0.0094	K	0.0086
F	0.0133	M	0.0076

The naked-eye stars are on the average very remote, with distances of 300 light-years or more.

The Rotation of the Galaxy

The discovery that the motions of the stars could not be considered entirely at random was made by Kapteyn from data other than radial velocities. He made use of the proper motions. If in any one region of the sky we count the numbers of stars moving in various directions we should expect, on the hypothesis of random motion, to obtain equal numbers in the various directions. However the effect of the solar motion would make more to appear to be moving toward the antapex. The result which we might expect to obtain, on the hypothesis of random motion combined with a solar motion, is illustrated in figure 2a. In this diagram the distance from the origin in any direction to the oval-shaped curve, represents

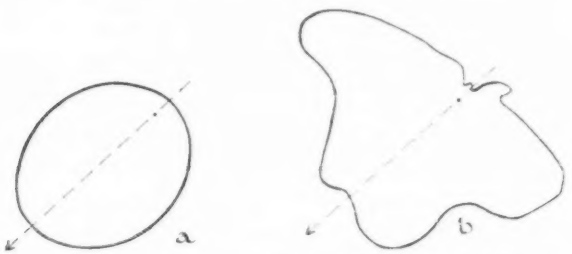


Fig. 2.—Curves showing the frequencies of proper motions—drift curves. The distance from the origin to the curve represents the fraction of the stars moving in that direction. (a) if the stars are moving at random combined with solar motion, (b) observed frequencies.

the number of stars which might be expected to be moving in that direction. The long axis of the oval is the direction of the antapex of the solar motion. The actual counts of the stars for one region in the sky give a diagram similar to 2b. This figure shows the effect of solar motion but it has two wings almost perpendicular to the solar motion. From a discussion of the proper motions in all parts of the sky Kapteyn announced that the stars could be divided into two main groups completely intermingled but drifting in opposite directions.

The apparent drifting of the stars in this manner has been shown to be due to a rotation of the stars about a distant centre. The stars

in our immediate vicinity, which constitute the naked-eye stars, are far removed from the centre, also the line of the preferential motion is at right angles to the line joining us to the distant centre, and the streaming in opposite directions arises from some of the stars revolving in one direction and others in the opposite direction.

It was shown by Oort that if such is the case, the radial velocities could be made to determine the distance to the centre, its direction and the period of revolution. That this is possible is due to the greater speeds of those stars in that part of the sky toward the galactic centre as compared with those on the half which is away from the centre. The solution becomes of greater weight if stars are employed which are far removed from the sun.

From an investigation of the B-type stars, which are very well suited for the purpose on account of their great average distance, Plaskett and Pearce have found the distance to the centre of rotation to be about 30,000 light-years and that the speed of revolution about the centre of the stars near us is 275 km. per sec. which carries them around the centre in a period of 225,000,000 years. It is quite likely that these figures may be subject to considerable revision as more data accumulate. The subject is a very interesting one and shows the power of radial velocities in untangling the complicated phenomena exhibited by the stars around us, and at the same time it emphasizes the need for more radial velocity determinations.

The Velocities of Remote Objects

The results discussed in the preceding sections are based on the velocities of stars for the most part brighter than the 8th magnitude. These stars lie within 1000 light years of the sun. The results have been interpreted on the basis that the whole extent of the universe is many times greater. This larger conception would seem fabulous if there were no more direct evidence of its existence, but there is other evidence of its reality. Direct photographs of the sky show, in addition to the fainter stars, a variety of other objects—the clusters and nebulae. Many of these objects may be seen in the telescope as faint patches of light or, in the case of clusters, as closely packed aggregations of faint stars. Their existence has

been known for over a century, but it was not till within the last twenty years that definite investigation of them was successfully made.

That we know so much about them to-day is largely due to the researches of Dr. Shapley of Harvard College Observatory. He has developed methods by which their distances can be deduced. The distance of the clusters is of the order of 20,000 to 100,000 light-years, and the geometrical centre of all the clusters known coincides with the centre of our universe. Investigations of the fainter stars have led to the conception of our universe as a huge flattened disk of stars, probably 100,000 light-years in diameter. The sun is situated fairly near one edge and a little above the central plane. The distances of the nebulae are of the order of millions of light-years and their distance, taken in conjunction with their angular diameters, gives their actual diameters. They have sizes of the same order as our own aggregation of stars. There are so many points of similarity between the spiral nebulae and our own system that few astronomers doubt that each of these objects constitutes a complete galaxy of stars similar to our own.

The individual stars comprised within these galaxies are much too faint to be observable for radial velocity with the instrument we possess. To observe them one has to be content with smaller dispersion and consequently larger probable errors. At first sight, it would seem useless to attempt velocities where the probable errors would be greater. It turns out however that the shift in the lines is so large that the percentage accuracy is comparatively high, even with probable errors as large as 100 km. per sec. The shift of the lines in many of these objects, if interpreted as due to radial velocity, corresponds to speeds up to 40,000 km. per sec. More surprising still, the farther the object is away the faster it moves and the velocity is always one of recession. This means that the complete universe, made up of our own galaxy and the outside nebulae which we consider to be other galaxies, is expanding. Whether this amazing result can receive a rational explanation remains for the future. At the present time it is considered as a necessary consequence of the peculiar relations of space, time and mass welded together in the theory of relativity.

It must be borne in mind that the theory of relativity does not

pretend to represent actualities, in fact rather denies the existence of ultimate facts. It aims only at a mathematical formulation of physical laws which will be consistent for all observers under all circumstances and will explain the observed phenomena. This of course is all any theory is required to do, but so many of the conclusions of the theory of relativity are paradoxical that unless they are prefaced by the words "it seems" or "as if", the theory leaves a certain atmosphere of contradiction behind it.

THE TOTAL ECLIPSE OF JUNE 19, 1936

Both of the solar eclipses occuring in 1936 are central. That of June 19 is a total eclipse but it is invisible in America.

This eclipse is invisible in America. The path of totality begins in E. Long. 16°, N. Lat. 33°; the middle (eclipse at local apparent noon) is in E. Long 101½°, N. Lat. 56½°; and the end is at E. Long. 179½°, N. Lat. 25½°. It starts in the Mediterranean Sea northeast of Tripoli, passes over Athens and not far from Constantinople, then over the Black Sea, over the towns of Omsk and Tomsk, then touches the north tip of Manchuria, then southeasterly across the peninsula north of Vladivostok, then across the sea of Japan and some north islands of Japan and ends far out in the Pacific Ocean. The maximum duration is about 2½ min.

Two American expeditions to observe the eclipse have been announced. One will be sponsored by the Harvard College Observatory and the Massachusetts Institute of Technology. It will be in charge of Dr. D. H. Menzel of Harvard assisted by Dr. J. C. Boyce of the M.I. The party's programme will be chiefly spectrographic with special effort directed to obtaining spectra of the chromosphere and the corona over a wide range of wave-lengths. Emphasis will be devoted to the infra-red region, at present almost a blank. A chief object is to obtain results which will allow identification of the coronal lines. The infra-red spectra will be largely for this purpose. This expedition will be located at Ak-Bulak, in the southern Ural mountains, where meteorological conditions are moderately favourable. The total eclipse will be at 8 a.m. and the altitude of the sun will be 36°.

The second expedition is under the joint auspices of the Georgetown University and the National Geographic Society and Dr. P. A. McNally, S.J., of the Georgetown Observatory, will be leader. This expedition will be located near Orenburg, where weather conditions are promising. It is to be hoped that Father McNally will be as successful as at the eclipse of August 30, 1932, on which occasion his photographs of the corona were probably the best obtained. The expedition will leave in April and return in July.

The eclipse of December 13-14 is annular and is visible only in the southern hemisphere. The path of annular eclipse begins in the Indian Ocean, passes over Broome, crosses Australia in a southeasterly direction and reaches the east coast about 200 miles north of Sydney at about 9 a.m. It then passes over the north island of New Zealand at about noon, Auckland being within the path, and then traverses a waste of waters.

RADIO TALKS OVER CFCT, VICTORIA, B.C.

By W. E. Harper

No. 77.—MINING FOR METEORITES

(December 18, 1934)

IN our discussion of meteors, we noted that their origin had been traced to comets. In the same year as witnessed the last great shower of the November meteors, namely 1866, a bright comet had been discovered earlier in the year whose period and path in the heavens was later computed from numerous observations to be identical with that of the meteoric swarm itself. Thus meteors are the remnants thrown off by the comet as it comes near the devastating rays of the sun. There is some repelling force exerted by the sun on the nucleus of the comet which causes particles large and small to stream off, away from it. These form the tail of the comet which gradually breaks down and leaves the individual particles pursuing the comet's own path, though trailing far behind. Several other similar cases are known and there is now no doubt that there is a very close connection between comets and meteors.

Meteoric bodies which are massive enough to get through our atmosphere and reach the earth before being entirely consumed are then known as meteorites and nearly every museum has a number of them. When such meteorites are analysed chemically the main constituents are found to be iron, calcium and silicon or, in brief, the composition may be described as iron and stone. It is only within the past year or two that the composition of those which burn up before reaching the earth has been determined. Millman, a former student worker at our own observatory, secured spectra of several while passing through the atmosphere and the analysis of their light shows the presence of iron, manganese, calcium, silicon, chromium and aluminium. Thus, if there ever had been any reason to doubt the family connection between those vanishing in the upper air and those reaching the earth it would be dispelled by this evidence.

The meteorites in our museums are in point of size only a matter

of a few inches each way; in extreme cases certainly only a few feet. The question I wish to discuss is what would happen if one hundreds of feet in diameter should come our way. The approximate mass of a meteorite of roughly spherical form and 100 feet in diameter would be of the order of 20,000 to 30,000 tons. What would happen? The question has a practical bearing, for men have for some time been engaged in drilling in Arizona in a great crater-like pit which is thought to have been caused by the impact of such a visitor from space, several hundreds or thousands of years ago. The diameter of this giant crater is 4000 feet; its walls rise 150 feet above the surrounding country whilst the bottom is 600 feet below the general level. Thousands of little fragments of iron meteorites have been found strewn about, and it gives every appearance of having been caused by an enormous meteorite or group of meteorites which, according to some scientists, weighed millions of tons.

There are two viewpoints on the formation of meteoric craters. The first one is that just presented, which assumed that the big meteorite would remain almost as intact as would one a foot in diameter. The little one buries itself a couple of feet in the ground while the more massive one plunges proportionately to a much greater depth. If this be true, it lends encouragement to those seeking to recover the buried minerals. The other viewpoint is that a meteorite weighing thousands of tons would strike at such a high velocity that it would be shattered and practically melted and vaporized. There would be, in effect, an explosion, and one less than a couple of hundred feet in diameter and weighing less than 100,000 tons might have produced the Arizona crater.

I remember attending a meeting at the Chicago Planetarium in September, 1930, where this latter viewpoint was presented very strongly by F. R. Moulton, a very able mathematician, and concurred in by E. W. Brown of Yale. Moulton gave numerous statistical results which he had worked out, one of which may be mentioned as an example. An iron meteor of spherical form weighing 125 tons and falling obliquely to the earth (let us say at 45°) would have a velocity of surface impact of 2.2 miles per second. If it struck a rocky surface the pressure would be 2400 tons per square inch and, we can well believe, it would explode. One of his conclusions was

that meteors of 1000 tons or more can reach the solid earth with such a velocity that they explode on impact and are almost completely vaporized.

A comparison can be made between theory and observation in the case of high-velocity bullets and conclusions may be drawn as to what the effect of striking should be for a large meteor. For this information I am indebted to Dr. C. C. Wylie, of the University of Iowa, who is a leading authority on the subject of meteors.

The standard army rifle has a muzzle velocity of 2700 feet per second. Calculations show that if a lead bullet is travelling at that velocity and is immediately stopped, the total energy would melt it and in addition would vaporize five per cent. of its mass. I understand that during the World War lead bullets from machine guns, while not actually penetrating the armour of tanks, would cause spurts of molten lead to go through cracks, burning the faces and eyes of the men inside. Thus observation accords with theory that the energy of striking would melt the bullet but not vaporize any appreciable amount.

If the lead bullet be travelling 5000 feet per second the bullet will not only be melted but 94 per cent. of its mass will be vaporized, according to theory. If the bullet be of iron, somewhat like the composition of a meteor, it will require a striking velocity of 14,000 feet per second to melt and vaporize it. The explosion would approximate that of the bullet's own weight of nitro-glycerin.

These theoretical results are again borne out by cold facts. Armour plate, 1½ inches thick, which is only slightly dented by armour-piercing bullets fired at 2700 feet per second, is wrecked by only a few rounds of the small lead bullets striking it with a velocity only 50 per cent. greater. It is the resulting explosion that does the damage.

To apply in the case of meteors, just imagine the bullet is a meteorite travelling 14,000 feet (about 2.6 miles) per second. Theory shows it will be completely vaporized and the energy of the explosion will equal that of an equal mass of nitro-glycerin. Thus a meteor whose diameter was of the order of a couple of hundred feet could, on exploding, create the gigantic crater pit in Arizona, and leave only fragmentary traces of itself.

If that be the true explanation of the crater—and it seems to be borne out by the close accordance of observation with theory in similar cases—then those who are drilling for minerals in the head of the original meteorite are doomed to disappointment.

No. 78.—SURFACE TEMPERATURES OF THE PLANETS

(January 15, 1935)

The heat supply of planets can have only two sources. It must either come from within or from without. Let us examine the possibilities of internal sources first.

In our own planet, with which we are most familiar and which can furnish us with evidence at first hand, we recognize that there is internal heat. The temperature rises about one degree centigrade every hundred feet as we go towards the centre of the earth. How far down this rate of increase extends we do not know, but at a depth of less than fifty miles the rocks must be very hot. The pouring forth of hot lava from active volcanoes and the spurting up of hot springs in many parts of the earth's surface is added testimony to an internal heat supply whose cause it is not our purpose at the moment to investigate.

But granted the existence of an internal supply, its effect on the surface temperature is very, very limited. Volcanoes and hot springs cover too small a fraction of the earth's surface to influence materially the average temperature and the general filtering outwards of the imprisoned heat through the solid rocks is so slow a process that it likewise adds but little to the store of surface heat.

Let us see how the other main planets fare in the matter of an internal supply of heat. Mercury, Venus and Mars have mean densities somewhat similar to the earth so that they too may be classed as solid bodies. As such, internal heat, if present, would find no easier escape to the surface than in the case of our own planet.

Omitting Pluto, about which little is known as yet, there remain the four major planets, Jupiter, Saturn, Uranus and Neptune. All these have mean densities much less than the four inner planets just discussed and the evidence suggests that they are largely gaseous in composition. That being the case, any supply of heat at the interior

would readily make its way out and raise the surface temperature.

Up until about ten years ago it was felt that these four large planets, while not hot enough to shine by their own light, were nevertheless quite hot. Since all the planets were supposedly thrown off from the sun at about the same time, it was only reasonable to assume that the larger bodies would retain their internal supply of heat for a much longer time than the smaller bodies. The changing cloud forms on Jupiter and Saturn which can be observed in a small telescope were considered as due to the uprushing of the heated material from below.

But this idea received a rude jolt when sensitive electrical thermometers were used about ten years ago to measure directly the temperatures of the moon, the planets and even the stars themselves. In a former talk I gave a description of one of these thermocouple devices and how they work; sufficient is it here to say that they can detect variations of temperature of the order of a millionth of a degree. Measurements by different workers agree that the surfaces of these outer planets are at temperatures of one or two hundred degrees below zero, so that molten matter as ordinarily understood is ruled out of the question.

We may summarize our discussion of the part played by internal heat in the surface temperatures of planets by stating that such action seems nil in the case of the outer planets and practically so in the case of the inner planets which are in the form of solid bodies. We are left, then, to consider the one and only source, that is, heat from outside.

While it is theoretically true that radiations are received on the earth and other planets from the stars and other celestial sources, practically the sun is the only source of heat for the planets of the solar system. Moreover, its radiations cover a wide range of wave-lengths, the heat radiation having a longer wave-length than the visual radiations by which we see the sun and these in turn being of greater length than the radiations by which we photograph objects.

The temperature to which a planet can rise as a result of the sun's heat depends upon two things: (1) the nature of the planet's surface and its atmosphere, and (2) its distance from the sun. In respect to the first factor, we are all aware that dark bodies absorb

more heat than white ones. If you do not believe this, try wearing dark clothes on a hot sunny day; you'll soon think of changing back to light coloured ones again. Probably the solid surfaces of the inner planets are not so markedly dissimilar in their rock covering as to make a big difference in the resulting relative temperatures from this factor alone.

When, however, we consider the atmospheric covering, or lack of one, it is different. Those that have an atmosphere are thus enabled to trap and hold a considerable portion of the sun's warming rays which would otherwise dissipate rapidly from the surface. Our greenhouses will serve as an illustration. The glass is tranparent to light rays but rather opaque to the longer heat rays. Light entering freely through the glass warms the soil and air inside but only a small fraction of such heat radiations can get out again through the glass and so the temperature rises. The earth's atmosphere acts in a similar manner, since it is transparent to light but opaque in many regions of the infra red, the home of the heat radiations.

Our satellite the moon has no atmosphere and consequently cannot retain for any great length of time the warming effects of the sun's rays. Extremes of temperature prevail between the regions turned towards (120°C.) and away from (–80°C.) the sun. The planet Mars also has a scanty atmospheric covering but the earth and her twin sister Venus are favoured with a blanketing atmosphere. In a still greater degree are the large outer planets, and it has been calculated that a dense atmospheric covering can in the manner of a greenhouse raise the temperature of a planet by an additional 25 per cent.

Consider the second factor upon which a planet's heat depends, its distance from the source—the sun. The farther away the planet, the less heat it will receive. The law telling just how much heat will be received is called the inverse square law. To illustrate, if one planet is twice as far away from the sun as another, it will receive only ¼ as much heat, if ten times as far away it will receive only 1/100 as much heat. Considering the earth's distance as the standard and calling it unity, or 1, we find that Jupiter is 5 times and Neptune 30 times as far removed from the sun as we are. Consequently, Jupiter will receive only 1/25 and Neptune 1/900 the amount of

solar heat that we do on the earth, when area for area is considered. On the other hand those planets like Venus and Mercury that are nearer to the sun than we are will receive, area for area, much more heat than we do.

Summing up, we may give a few figures to illustrate the temperatures arrived at for the various planets, taking into account all the factors just mentioned. These theoretical temperatures have been confirmed by the heat-measuring devices referred to:

Mercury (sunlit side)	350°C.	Jupiter	–100°C.
Venus (mean)	17°	Saturn	–150°
Earth (mean)	14°	Uranus	–180°
Mars (warmest parts)	12°	Neptune	–200°

REVIEW OF PUBLICATIONS

Die Beobachtung Veränderlicher Sterne, by Dr. Rolph Müller. 20 pages. Leipzig, J. A. Barth, 1935. Price RM 2.40.

This publication forms an introduction to the practical visual observation of variable stars. The author is one of the editors of *Die Sterne*, the journal from which this article is reprinted, and has for some time been particularly interested in the astronomical work of amateurs. He explains in some detail the classical Argelander "step" method of estimating the brightness of one star relative to comparison stars, and the evaluation of these steps in terms of stellar magnitudes for any particular observer. He also discusses the importance, in visual estimates of brightness, of the relative colours of the stars, and defines the Osthoff scale of colour. The method of determining periods and deriving light curves of variables is outlined, and some of the difficulties of observation and reduction are presented. A nomogram, reprinted from *Popular Astronomy*, 1935, is added, owing to its importance in determining extinction coefficients.

It is interesting to note that these instructions for amateur observers contemplate the inclusion of short-period stars for study, in contrast to the work of the A.A.V.S.O., which has found it advisable to restrict visual observation to long-period variables only.

F. S. H.

Amateur Telescope Making, edited by Albert G. Ingalls, Associate Editor of the *Scientific American*. Fourth edition, over 500 pages, $5\frac{1}{2}\times7\frac{1}{2}$ inches, with many illustrations. N.Y., *Scientific American*, 1935. Price $3.00.

It is a great pleasure to see a book like this succeed. How it, arose is fully explained in the preface. The first edition, 102 pages 3400 copies, was published in 1926 and was gone by 1928. In that year a second edition, running to 285 pages, was issued and its 5400 copies were exhausted in 1932. The book was then fully revised and extended to nearly 500 pages and the third edition (5000 copies, I believe) came out in November 1932. In three

years this was gone and the present fourth edition appeared in December last. It contains new sections on mountings (p. 130), "HCF" laps (p. 149), drives (p. 154), machine polishing (p. 234), sidereal time (p. 337), replacing older sections; also some new notes and corrections.

The book is an admirable compendium for the amateur telescope maker and for the user of the instrument after it is completed. I strongly recommend the worker to get a copy of the book for himself, not just borrow one. He should have it beside him for constant reference. There is nothing like making the book one's own, both in contents and in the material volume.

It is worthy of remark that the genial and lively Editor has acceded to numerous requests and has allowed his portrait to appear on the last page before the Index.

C. A. C.

Worlds Without End, by H. Spencer Jones, Astronomer Royal. Pages xv, 329, $5\frac{1}{2}\times 8$ in. Plates 32. N.Y., Macmillan, 1935. Price $3.

This is a book for the general reader, of the arm chair variety rather than the observing amateur. The volume before the reviewer is set up and printed in the United States and a creditable production it is.

There are thirteen chapters: (1) The earth—our home; (2) Our nearest neighbour—the moon; (3) The sun's family of planets; (4) Life in other worlds; (5) Comets and shooting stars; (6) The nearest star—the sun; (7) Giant and dwarf stars; (8) The stars—our blood relatione; (9) Twin stars, pulsating stars and new stars; (10) Our stellar universe; (11) Celestial catharine-wheels; (12) The age and evolution of the stars; (13) What was—what is to be.

From these titles the reader will expect a thoroughly modern treatment and he will not be disappointed. A larger proportion of space than usual is devoted to the stellar universe, while chapters 4, 12 and 13 discuss in an able manner those cosmological questions which have been made so attractive by such writers as Eddington and Jeans.

The author gives a comprehensive account of the investigations and discoveries regarding the earth, the moon, the sun and other

bodies—possibly too condensed in some instances—and presents the latest physical theories (the nature of the atom, etc.) and their astronomical implications with especial clearness and skill. In approaching a problem, such as the beginning of life on the earth, he states the different viewpoints and then logically develops his arguments. At the very end of the book, after outlining views held regarding what will happen to the universe, he makes the sensible remarks:

> In the present condition of knowledge, we are free to consider it equally possible either that the Universe is slowly but inexorably pursuing its course towards old age and inevitable death, or that it is destined to undergo periodic rejuvenation and to live its life over and over again. . . . As a practical astronomer, I must emphasize that these are at present realms of speculation. Observation is the touchstone of every theory or hypothesis in science; the two alternative but divergent theories as to the future of the Universe cannot yet be tested by astronomical observations. Until this is possible, we are free to select whichever we prefer.

The book may be highly commended.

C. A. C.

PLATE V.

THE SPECTRUM OF A BRIGHT LEONID.

Photographed at the Dunlap Observatory at 1.48 a.m., Nov. 18, 1935. Spectrograph is composed of 30° prism and F4.5 lens with focal length 5.3 in. Approximate wave-lengths, in angstroms, are indicated. Note the strong violet intensity of the meteor on a plate strongly sensitive to red. The spectrum of α Andromedae, Alf, appears to the upper right. (See Meteor News).

METEOR NEWS

Observations relating to meteors and meteorites are cordially invited.

(With plate V)

Photographic Ovservations of the Leonids, 1935

Photographic observations of the 1935 Leonids were undertaken by the writer at the Dunlap Observatory. Unfortunately the sky was completely overcast on all nights near the maximum except that of Nov. 17-18. Three small meteor spectrographs, used previously during similar programmes, were exposed on the above date. Ilford Meteor Panchromatic plates were used in all three cameras. One meteor spectrum was photographed, that of a blue Leonid appearing at 1.48 a.m., magnitude −3, leaving a persistent train of 7 seconds duration. This spectrum is reproduced in Plate V. It is of Type Z and is one of the first meteor spectra to show the entire range of wave-lengths from λ3500 in the ultra violet to λ6600 in the red. Type Z, where practically all the lines are given by neutral iron, seems to correspond to exceptionally low meteors. This is the first spectrum of a meteor of any well-known shower that has been of this type and it would be very interesting to know if this was an unusually low Leonid. Unfortunately, up to the present, the writer has received no other observations of this object so that it is probable we shall never know its height above the earth's surface. The spectrum shows a detail of over 40 bright lines but the definition is not as good as it should be owing to an unforeseen variation in the plate holders of the camera with which it was photographed.

Both Mr. D. A. MacRae and Mr. R. B. Laing made exposures at the Dunlap Observatory with direct cameras. They each photographed a Leonid trail, the meteors being of magnitude −2 and 0 respectively. The details of the photographic exposures are listed in Table I.

TABLE I

Photographic Observations of the Leonids, 1935
(Dunlap Observatory, Nov. 17-18, 1935)

	Total Exposure Time	Plates Exposed	Meteors Photographed
Spectrophotography.....	15.8 hrs.	29	1
Direct Photography.....	5.7 "	13	2

VISUAL OBSERVATIONS OF THE LEONIDS, 1935

Very few visual observations of the Leonids were made owing to poor weather. Groups observed, however, at the Dominion Observatory, Ottawa, on Nov. 16-17 and at the Dunlap Observatory, Richmond Hill, on Nov. 17-18. The personnel of these two groups was as follows:

Nov. 16-17, Ottawa: Miss M. S. Burland, M. M. Thomson, K. Buckthought, Miss G. Jolly, Miss E. Waters.

Nov. 17-18, Richmond Hill: R. J. James, R. B. Laing, D. A. MacRae, Miss R. J. Northcott, Miss F. S. Patterson, P. M. Millman.

The observations were carried out as in previous programmes, all meteors, with very few exceptions, being timed to the nearest second and plotted. The actual numbers of meteors observed in twenty minute intervals are recorded in Table II.

TABLE II

VISUAL OBSERVATIONS, LEONIDS, 1935

	Ottawa, Nov. 16-17		Richmond Hill, Nov. 17-18	
E.S.T.	L	NL	L	NL
12.10-12.30			0	2
12.30-12.50			6	3
12.50- 1.10			6	2
1.10- 1.30	1	3	5	5
1.30- 1.50	0	3*	6	6
1.50- 2.10	2	1*	8	6
2.10- 2.30	3	4*	2	5
2.30- 2.50			3	5
2.50- 3.10			5	5
3.10- 3.30	3	2*	5	5
3.30- 3.50	1	2*	5	6
3.50- 4.10			4	1
4.10- 4.30			8	5
4.30- 4.50			5	1
4.50- 5.10			8	5
5.10- 5.30			7	2
5.30- 5.50			6	4
5.50- 6.10			3	2
6.10- 6.30			1	0
6.30- 6.50			1	0
Totals	10	15	94	70

*Haze and clouds

The hourly rates of Leonids and Non-Leonids for Nov. 17-18, reduced to six observers plotting, are shown in Figure 1. Here, each dot represents the reduced hourly rate for one whole hour centred at the corresponding position. It will be seen that the Leonid rate was fairly constant throughout the last half of the night. In spite of the haze and clouds at Ottawa it would seem that the Leonid rate could not have been much higher on the night of Nov. 16-17 than on the following night. The magnitude distribution for Nov. 17-18 is listed in Table III. The Non-Leonids were on the average a whole magnitude fainter than the Leonids. This difference is considerably greater than usual.

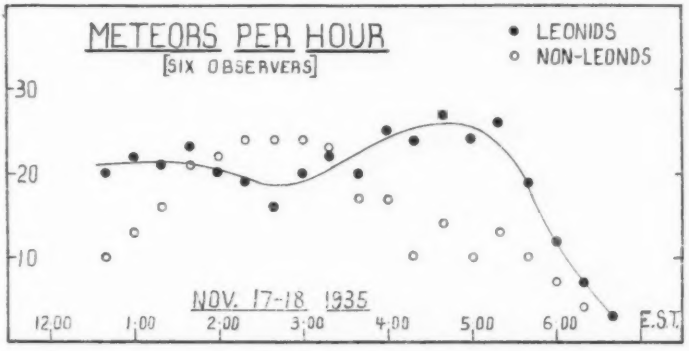


FIG. 1.—The hourly rates of meteors observed at the Dunlap Observatory, November 17-18, 1935.

TABLE III

MAGNITUDE DISTRIBUTION, NOV. 17-18, 1935

Mag.	−4	−3	−2	−1	0	1	2	3	4	5	Totals	Mean Mag.
Leonids	1	3	4	3	12	20	23	24	4		94	1.38
Non-Leonids				1	4	7	19	30	5	1	67	2.38

THE RELATIVE NUMBERS OF LEONIDS DURING RECENT YEARS

For the past five years the writer has conducted programmes for visual observation of the Leonid meteors, observations being

made on all clear nights near the maximum date. All programmes were carried out under the same instructions, the observers plotting and the times being recorded to the nearest second by a recorder. The hourly rates were reduced to six observers by a uniform system of reduction factors since the observing groups varied in size from three to thirty-five observers. Though many nights near maximum were missed owing to cloudy weather it is of interest to compare the results of various years because of the uniformity of the method by which the observations were made. Table IV lists briefly the results for all nights when a clear sky made a good series of observations possible. The third column gives the total

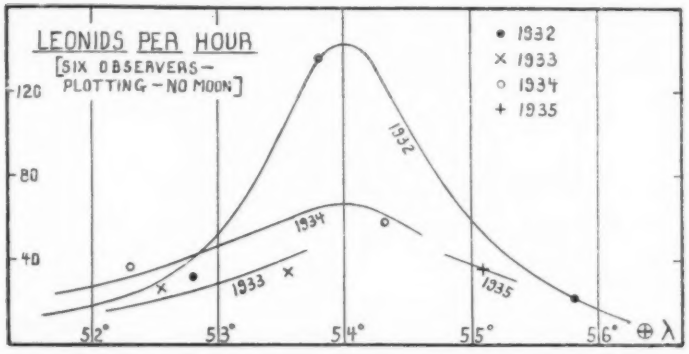


FIG. 2.—Hourly Leonid rates plotted against the heliocentric longitude of the earth.

numbers of Leonids observed on the date in question and the fourth column lists the average hourly rate for six observers for the two hours centred at 4.00 a.m. local mean time. The age of the moon is given in the last column, .25 being first quarter, .50 full moon, and .75 last quarter. To make a comparison of the rates for different years the moon should be taken into account. Since the Leonid observations were made during the morning hours the only real influence of the moon on the observed rates was in 1932 and 1935. By comparing the magnitude distributions of both Leonids and Non-Leonids for these two years with those of the other years it was concluded that the 1932 rates should be multiplied

TABLE IV

VISUAL LEONID OBSERVATIONS, 1931-1935

Place	Date	Leonids Observed	Hourly Rate (3-5 a.m. L.M.T.)	Average Age of Moon
Blue Hill Obs., Mass.	1931 Nov. 11-12	23	20	.12
	13-14	41	17	
Harvard Oak Ridge Obs., Mass.	1932 Nov. 14-15[1]	55	16	.58
	15-16	368	68	
	17-18	24	11	
Dunlap Obs., Ont.	1933 Nov. 14-15[2]	65	26	.94
	15-16	160	34	
Dunlap Obs., Ont.	1934 Nov. 14-15[3]	105	36	.33
	16-17	175 (136, Belwood Ont.)	58	
Dunlap Obs., Ont.	1935 Nov. 17-18	94	24	.78
Total Leonids.....		1246		

[1]Harvard Bulletin 891, p. 6, 1933.
[2]Jour. R.A.S.C., Vol. 28, pp. 137, 175, 1934.
[3]Jour. R.A.S.C., Vol. 29, p. 25, 1935.

by 2.0 and the 1935 rates by 1.5 to reduce them to no moon. The resulting rates are plotted against the heliocentric longitude of the earth in Figure 2. The rates for the Leonids from 1928 to 1934 as published in *Popular Astronomy* by Olivier and Wylie seem to indicate an average curve of relative rates similar to that marked 1932 in Figure 2, with an average for the Leonid maximum at about heliocentric longitude 54.0 degrees. There should certainly be great variations in the form of this curve from year to year and from place to place on the earth's surface. The results here reported would indicate, however, that the Leonids were much more numerous in 1932 than in the last three years and that of these last three years most Leonoids probably appeared in 1934. No definite conclusions can be drawn from the two nights during which observations were made in 1931, since they are too far from

the maximum. Professor Olivier has published rates for the maximum night in 1931.[4] By making allowance for plotting and the expected numbers of Non-Leonids, it is probable that Olivier's rate for 1931 on our scale would be about 220, thus indicating between one and a half and two times as many Leonids in 1931 as in 1932.

For 3 to 5 a.m. on the ten nights listed in Table IV the average hourly rate of Non-Leonids, reduced to six observers and no moon, was 25±6. The magnitude distribution of 1283 Leonids observed 1931-1935 is given in Table V.

TABLE V

MAGNITUDE DISTRIBUTION OF 1283 LEONIDS

Mag.	−6	−5	−4	−3	−2	−1	0	1	2	3	4	5	6	Mean Mag.
	1		1	7	21	45	96	249	344	339	137	40	3	2.03

If N_m is the number of meteors of magnitude m then, down to first magnitude, the following law holds:

$$\frac{N_{m+1}}{N_m} = 2.41 \pm .14.$$

If we assume that the rates in Figure 2 represent half the actual number of meteors down to magnitude 5 visible from one station, and that as an average, meteors are completely observed within a radius of 170 miles, then it is possible to obtain a very rough idea of the density of Leonids in space. The maximum rate for 1932 gives us one Leonid, fifth magnitude or brighter, in each 40 million cubic miles of space, or an average distance between objects of a minimum mass corresponding to magnitude five of between 300 and 400 miles. This minimum mass, following the computations of Öpik, is probably of the order of 0.001 to 0.0001 gm., and the average individual mass of all Leonids visible to the naked eye between 0.1 and 0.01 gm. A volume of the size of the earth, taken from the part of the Leonid swarm encountered in 1932, would then contain only from 1 to 1000 gms. of meteoric material exclusive of meteors invisible to the naked eye.

P.M.M.

[4] *P.A.* Vol. 40, p. 47, 1932.

NOTES AND QUERIES

Communications are invited, especially from amateurs. The Editor will try to secure answers to queries.

New Velocities of Extra-galactic Nebulae

The interpretation of the red shift in the spectra of the extra-galactic nebulae is the most interesting of astrophysical problems at the present time, and further observational results are much desired. At the recent meeting of the National Academy of Science a paper on this subject was presented by M. L. Humason of the Mount Wilson Observatory, of which the following abstract appeared in *Science*:

During the past four years the apparent velocities of 100 extra-galactic nebulae have been obtained at Mount Wilson. They include velocities from 6 clusters, 5 groups and 56 isolated nebulae. As found in previous investigations, they are predominantly velocities of recession ranging from only a few hundred km./sec. for the nearer and brighter objects, to velocities of the order of +40,000 km./sec. in the Boötes cluster and in the second Ursa Major cluster. Both clusters are estimated to be at distances of about 70 million parsecs. The observations cover a range about forty times that available in Hubble's first formulation of the velocity-distance relation and indicate that the relation is still sensibly linear out to the distance of these clusters. The constant of the linear relation,

velocity = 560 km./sec. per million parsecs,

remains essentially unchanged. In the Virgo cluster 25 new velocities have been obtained. These, with velocities previously known, show an average range of 500 km./sec. around a mean of +1200 km./sec. The apparent photographic magnitudes of the objects observed range from 10.0 to 15.0 and the mean velocity of the fainter members is approximately the same as that of the brighter. Velocities of isolated nebulae, including those previously known, have been used by Hubble and Humason to derive the velocity-distance relation for isolated nebulae. The relation parallels that for the clusters but is displaced one magnitude toward the brighter side. This displacement occurs because the nebulae observed were selected on the basis of apparent magnitude, a selection which favours the systems of high luminosity if the spatial distribution is considered. It is in the direction and of the order expected. Only 6 nebulae have negative velocities. Three of them, NGC 247, 253 and IC 342, are large and relatively near objects. The spectra of two others, NGC 4569 and NGC 6207, may be those of stars projected on the nuclei. Comparison of the spectral type with the nebular type shows that late-type spirals are decidedly bluer than E, Sa or Sb nebulae. The

mean spectral types for these groups are: E 0-7, G 3.6; Sa, G 3.4; Sb, G 1.6; Sc, F 8.8. The mean spectral type of faint nebulae is approximately the same as that of the brighter nebulae. The mean spectral type of the 100 objects observed is G 2.5.

Smoking in Boston a Hundred Years Ago

The following is quoted from a letter written by a citizen of York (now Toronto) making a visit to Boston. It is dated Sunday, August 18, 1933:

> This day we passed through a more even, though yet a hilly, country and there was nothing particular to catch the eye until we arrived at Lowell, a village 25 miles from Boston—grown up within 12 years and now has a population of 12,000 souls. It has a great number of good buildings, and several large manufactories of Cotton. We arrived at Boston about 7 o'clock in the evening and strolled through the streets, the first thing which struck us was to find that not a single individual (ourselves excepted) was seen smoking segars in the Street, and upon inquiry we found that it was contrary to the Corporation regulations.—*Mary's Rosedale and Gossip of Little York* by A. G. Meredith, p. 91 (1928).

Rejects Daylight-saving Time

It is worth recording that Victoria, B.C., on December 12, 1935, by popular vote rejected "summer" time for 1936 by 2625 to 1943. Was this due to the scientific sobering effect of the D.A.O.?

C. A. C.

The Royal Astronomical Society of Canada

OFFICERS FOR 1935

Honorary President—THE HON. LEONARD J. SIMPSON, M.D., Minister of Education for the Province of Ontario.
President—LACHLAN GILCHRIST, M.A., PH.D., Toronto.
First Vice-President—R. E. DELURY, M.A., PH.D., Ottawa.
Second Vice-President—J. A. PEARCE, M.A., PH.D., Victoria.
General Secretary—R. A. GRAY, B.A., 198 College St., Toronto.
General Treasurer—J. H. HORNING, M.A., Toronto; *Recorder*—E. J. A. KENNEDY, Toronto.
Librarian—R. A. GRAY, B.A., Toronto; *Curator*—R. S. DUNCAN, Toronto.
Council—D. S. AINSLIE, M.A., PH.D., Toronto; F. NAPIER DENISON, Victoria, B.C.; MISS A. VIBERT DOUGLAS, PH.D., Montreal; WM. FINDLAY, PH.D., Hamilton; E. A. HODGSON, M.A., PH.D.; P. M. MILLMAN, PH.D., Toronto; E. H. MCKONE, B.A., B.PAED., LONDON, Ont.; J. PATTERSON, M.A., Toronto; JOHN SATTERLY, M.A., D.Sc., Toronto; L. A. H. WARREN, M.A., PH.D., Winnipeg; and Past Presidents—SIR FREDERIC STUPART; C. A. CHANT, M.A., PH.D.; A. T. DELURY, M.A.; L. B. STEWART, D.T.S.; J. S. PLASKETT, D.Sc., F.R.S.; A. F. MILLER; J. R. COLLINS; W. E. W. JACKSON, M.A.; R. M. STEWART, M.A.; A. F. HUNTER, M.A.; W. E. HARPER, M.A.; H. R. KINGSTON, M.A., PH.D.; R. K. YOUNG, M.A., PH.D.; and the presiding Officer of each Centre as follows—A. R. HASSARD, K.C., Toronto; A. H. MILLER, Ottawa; G. R. LIGHTHALL, Montreal; MAJOR E. H. ANUNDSON, London; L. T. S. NORRIS-ELYE, Winnipeg; H. BOYD BRYDON, Victoria; PROF. WM. FINDLAY, Hamilton; W. H. GAGE, M.A., PH.D., Vancouver; DR. E. H. GOWAN, Edmonton.

TORONTO CENTRE

Honorary Chairman—DR. C. A. CHANT; *Chairman*—A. R. HASSARD, K.C.; *Vice-Chairman*—E. J. A. KENNEDY
Secretary—S. C. BROWN, 22 Kings Lynn Rd., Etobicoke, Ont.
Recorder—F. L. TROYER; *Treasurer*—J. E. MAYBEE; *Curator*—R. S. DUNCAN
Council—DR. D. S. AINSLIE; DR. L. GILCHRIST; F. L. HARVEY; DR. F. S. HOGG; J. H. HORNING; T. H. MASON; DR. P. M. MILLMAN; REV. C. H. SHORTT; DR. R. K. YOUNG; and the Past-Chairmen—A. F. HUNTER, J. R. COLLINS, and R. A. GRAY

OTTAWA CENTRE

Honorary President—R. GLENN MADILL; *President*—A. H. MILLER
First Vice-President—J. MCLEISH; *Second Vice-President*—MISS M. S. BURLAND
Secretary—M. M. THOMSON, Dominion Observatory; *Treasurer*—A. W. GRANT
Council—DR. E. A. HODGSON; DR. A. WILLARD TURNER; C. A. FRENCH; J. P. HENDERSON; F. W. MATLEY; and all Past Presidents

MONTREAL CENTRE

Honorary President—MGR. C. P. CHOQUETTE; *President*—GEORGE R. LIGHTHALL
First Vice-President—DR. JULIAN C. SMITH; *Treasurer*—DR. A. VIBERT DOUGLAS
Second Vice-President—C. A. FERRIER
Secretary—J. W. SPEIGHT (temporary), MacDonald Physics Laboratory, McGill University
Council—DR. A. S. EVE; LT.-COL. W. E. LYMAN; G. HARPER HALL; DR. L. V. KING; E. RUSSEL PATERSON; HENRY F. HALL; F. DEKINDER; DR. C. C. BIRCHARD

LONDON CENTRE

Honorary President—DR. H. R. KINGSTON; *President*—MAJOR E. H. ANUNDSON
Secretary—DR. G. R. MAGEE, 562 Queen's Ave.; *Treasurer*—DR. H. S. WISMER
Vice-President—F. C. BENSON
Council—MRS. S. G. HUNGERFORD; J. MIDDLEBROOK; MISS A. TORY; REV. R. J. BOWEN; A. J. DOKE

WINNIPEG CENTRE

Honorary President—DR. J. S. PLASKETT, C.B.E.; *President*—L. T. S. NORRIS-ELYE
First Vice-President—A. V. PIGOTT; *Treasurer*—J. H. KOLB
Second Vice-President—A. R. MCCAULEY
Secretary—W. H. DARRACOTT, 773 McMillan Avenue, Winnipeg
Council—D. R. P. COATS; MRS. S. C. NORRIS; MRS. E. L. TAYLOR; R. D. COLQUETTE; MISS C. A. ARMSTRONG; MRS. J. C. HOWEY

VICTORIA CENTRE

Honorary President—JAMES DUFF, M.A.; *President*—H. BOYD BRYDON
First Vice-President—CHARLES HARTLEY
Second Vice-President—LIEUT.-COMNDR. H. R. TINGLEY
Secretary-Treasurer—GORDON SHAW, 105 Woolworth Bldg., Victoria, B.C.
Directors—W. BURTON; A. DEAKIN; T. H. GREENWAY; W. HOBDAY; W. F. HOLDRIDGE; ROBERT PETERS; and Past-Presidents—W. E. HARPER, M.A.; DR. J. A. PEARCE; DR. C. S. BEALS; P. H. HUGHES, MUS. BAC.

HAMILTON CENTRE

Honorary President—MRS D. A. MARSH; *President*—PROFESSOR WM. FINDLAY
Vice-Presidents—PROF. A. E. JOHNS; T. H. WINGHAM; W. T. GODDARD
Secretary—NORMAN GREEN, 186 Rosslyn Avenue N., Hamilton, Ont.
Treasurer—G. CAMPBELL; *Curator*—T. H. WINGHAM
Council—DR. G. JACKSON; S. W. SCAMMELL; MRS. S. W. SCAMMELL; J. A. MARSH; REV J. SAMUEL; W. S. MALLORY; J. S. TAYLOR; REV. E. F. MAUNSELL; G. FREEMAN

VANCOUVER CENTRE

Honorary President—DEAN D. BUCHANAN; *President*—DR WALTER H. GAGE
First Vice-President—H. P. NEWTON; *Treasurer*—A. OUTRAM
Second Vice-President—MRS. C. V. ROBSON
Secretary—C. A. MACDONALD, 3042 York Ave., New Westminster, B.C.
Council—MRS. LAURA ANDERSON; H. C. B. FORSYTH; J. L. BENNETT; M. A. MCGRATH; H. A. PITMAN; S. RICHMOND; SETO MORE; J. W. MOORE; J. W. PICKIN; and Past Presidents—DR. G. M. SHRUM; J. TEASDALE; and DR. W. URE

EDMONTON CENTRE

Honorary President—DR. J. W. CAMPBELL; *President*—DR E. H. GOWAN
Vice-President—F. S. SIMPSON; *Treasurer*—W. H. POOLE
Secretary—MRS. J. A. CLARKE, 7852 Jasper Avenue, Edmonton
Council—M. H. HILTON; MISS E. M. VALENS; F. L. CROSBY; W. A. MCAULEY; A. B. MCKIM

THE ROYAL ASTRONOMICAL SOCIETY OF CANADA

This Society was incorporated in 1890 under the name of The Astronomical and Physical Society of Toronto, and assumed its present name in 1903.

The Society has active Centres in Montreal, P.Q.; Ottawa, Toronto, Hamilton, and London, Ont.; Winnipeg, Man.; Edmonton, Alta.; Vancouver and Victoria, B.C.

The Society publishes a monthly JOURNAL containing each year about 500 pages and a yearly OBSERVER'S HANDBOOK of about 80 pages. Single copies of JOURNAL or HANDBOOK are 25 cents.

Membership is open to anyone interested in astronomy. Annual dues, $2.00; life membership, $25.00. Publications are free to members, or may be subscribed for separately. Apply to the General Secretary, 198 College St., Toronto, or to the local secretary of a Centre.

Extract from the By-Laws: Candidates who are elected to membership will be attached to a particular Centre, or to a section known as *Members at Large*. Members of the Society who live outside of Canada, or in a province in which there is no Centre of the Society will be considered *Members at Large* and not attached to any particular Centre, unless these members are expressly nominated for membership and attachment to a particular Centre. Members may be transferred from one Centre to another, or to the section *Members at Large* by the Council of the Society if written application for such transfer is made by such member to the Council.

The Society has for Sale:

General Index to the TRANSACTIONS of the R.A.S.C., 1890-1905, and the JOURNAL, Vols. 1 to 25, 1907-31.

Compiled by W. E. Harper, Assistant Director, Dominion Astrophysical Observatory, Victoria, B.C.

Pages, 122; Price, $1.00, postage 5c. extra.

New Materials for the History of Man—The Festival of the Dead, by R. G. Haliburton.

This is a research into the Year of the Pleiades, first published at Halifax N.S., in 1863; reprinted by the R.A.S.C. in 1920.

Pages, 126; Price, $1.00, postage 5c. extra.

Send Money Order to 198 College St., Toronto.